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Description

ELECTRIC POWER UNIT FOR ELECTRIC DISCHARGE SURFACE TREATMENT AND METHOD OF ELECTRIC DISCHARGE SURFACE TREATMENT

Technical Field

The present invention relates to improvements in an electric power unit for electric discharge surface treatment, and also the present invention relates to improvements in a method of electric discharge surface treatment, by which a hard coat made of electrode material or a hard coat made of electrode material, which has reacted by electric discharge energy, is formed on a surface of a workpiece by energy of electric discharge when the electric discharge is generated between the electrode for electric discharge surface treatment and the workpiece.

Technical Art

Concerning the prior art by which a hard coat is formed on a surface of a workpiece so as to endow the workpiece with a corrosion resistance and abrasion resistance property, for example, Japanese Patent Laid-Open No.148615/1993 discloses a method of electric discharge surface treatment. According to the patent publication, there is provided a method of electric discharge surface

treatment of metal including the steps of: conducting a primary processing (accumulation processing) in which a pressed powder electrode, which is an electrode for electric discharge surface treatment formed by compressing powder of WC (tungsten carbide) and Co (cobalt), is used; and conducting a secondary processing (remelting processing) in which the electrode is replaced with an electrode made of copper, the electrode consumption of which is relatively small. According to this method, it is possible to form a hard coat having a strong adhering force with respect to steel, however, it is impossible to form a hard coat having a strong adhering force with respect to sintered material such as cemented carbide.

However, according to the investigations made by the present inventors, the following knowledge has been found out. When an electrode for electric discharge surface treatment made of material such as Ti (titanium) capable of forming a hard carbide is used and electric discharge is generated between the electrode and metal of a workpiece, it is possible to form a strong hard coat on the metal surface of the workpiece without being subjected to the process of remelting. The reason why the strong hard coat is formed on the metal surface is that the electrode material, which has consumed by electric discharge, reacts with C (carbon) which is a component of processing

solution, so that TiC (titanium carbide) can be created. Also, the following knowledge has been found out. When a pressed powder electrode, which is an electrode for electric discharge surface treatment made of metal hydride such as TiH_2 (hydrogenation titanium), is used and an electric discharge is generated between the pressed powder electrode and the metal of a workpiece, it possible to form a hard coat more quickly, the adhering property of which is higher than that of a case in which Ti is used. Further, the following knowledge has been found out. When a pressed powder electrode, which is an electrode for electric discharge surface treatment in which hydrogenation compound such as TiH_2 is mixed with other metal or ceramics, is used and an electric discharge is generated between the pressed powder electrode and the metal of a workpiece, it is possible to quickly form a hard coat of various hardness and abrasion resistance property.

The above method is disclosed, for example, in Japanese Patent Laid-Open No.192937/1997. Fig.4 is an arrangement view showing an example of the device used for the electric discharge surface treatment described above. In Fig.4, reference numeral 1 is a pressed powder electrode which is an electrode for electric discharge surface treatment composed of compressed powder of TiH_2, reference numeral 2 is a workpiece, reference numeral 3 is a

processing tank, reference numeral 4 is a processing solution, reference numeral 5 is a switching element for switching a voltage and current impressed upon between the pressed powder electrode 1 and the workpiece 2, reference numeral 6 is a control means for controlling by turning on and off the switching element 5, reference numeral 7 is an electric power unit, reference numeral 8 is a resistor, and reference numeral 9 is a hard coat which has been formed. According to the above structure, when an electric discharge is generated between the pressed powder electrode 1 and the workpiece 2, the hard coat 9 can be formed on a surface of the workpiece 2 made of steel or cemented carbide by the electric discharge energy. In this structure, the switching element 5, control circuit 6, electric power unit 7 and resistor 8 correspond to an electric power unit for electric discharge surface treatment to determine a wave-form of a pulse of an electric discharge current when the electric discharge surface treatment is conducted.

In the above conventional electric power unit for electric discharge surface treatment, an electric discharge current pulse, the wave-form of which is rectangular, is basically used. As shown in Fig.5, when peak value Ip of the electric discharge current and pulse width T are

changed, the thickness of a coat formed on a workpiece is adjusted.

Figs.6A and 6B are schematic illustrations for explaining an electrode material which adheres to a workpiece. Fig.7 is a view showing changes in the electric current density and the diameter of the electric discharge arc column when the time passes from the start of electric discharge. In Figs.6A and 6B, reference numeral 1 is an electrode for electric discharge surface treatment, reference numeral 2 is a workpiece, reference numeral 10 is an electric discharge arc column, reference numeral 11 is an electrode component emitted by vaporization and explosion when it is heated quickly, and reference numeral 12 is an electrode component adhering to the workpiece 2. As shown in Figs.6A and 7, immediately after the generation of electric discharge, the diameter of the arc column 10 is small, and the density of electric current is very high. Different from a normal electrode for electric discharge treatment for conducting a removal processing, heat conduction and mechanical strength of the electrode for electric discharge surface treatment are intentionally decreased for enhancing the productivity of surface treatment work. Accordingly, as shown in Fig.6A, when the density of electric current is high, a portion of the electrode 1 for electric discharge surface treatment close

to the electric discharge arc column 10 is quickly heated, and the portion of the electrode 1 for electric discharge surface treatment is vaporized and exploded and scattered to the periphery (into the processing solution). In this case, the electrode component 11, which has been quickly heated, vaporized and exploded, is quickly cooled by the processing solution. Therefore, it can not become a hard coat of the workpiece 2. On the other hand, when the density of electric current is appropriate, as shown in Fig.6B, the diameter of the electric discharge arc column 10 is extended. Therefore, a wide range of the electrode 1 for electric discharge surface treatment is heated, so that a quantity of electrode component 12 adhering to the workpiece 2 is raised.

As described above, according to the electric discharge current of a rectangular wave-form (shown in Fig.5) which is created by the conventional electric power unit for electric discharge surface treatment, even when peak value Ip of the electric discharge current pulse is increased for enhancing the productivity of surface treatment, a ratio of adhesion of the electrode material to the workpiece is low. Consequently, the ratio of adhesion of the electrode material to the workpiece is about 10wt% to 50wt%. That is, the electrode material is wasted, so that the cost of surface treatment is increased.

According to the electric discharge surface treatment method, the electrode material is emitted by heat of the electric discharge, and a portion of the thus emitted electrode material melts and adheres to the surface of the workpiece so that a hard coat can be formed. Accordingly, the electric discharge energy has two functions. One is a function of emitting the electrode material, and the other is a function of emitting the electrode material and melting the workpiece to each other. Figs.8A and 8B are photographs showing a surface of a workpiece in the case where electric discharge surface treatment is conducted on a workpiece made of steel by one shot of electric discharge current pulse. The photograph shown in Fig.8A shows a case in which a quantity of emitted electrode material is too large, and Fig.8B shows a case in which a quantity of emitted electrode material is too small. In the case where the quantity of emitted electrode material is too large as shown in Fig.8A, the electrode material, which has been emitted by electric discharge energy, can not be sufficiently melted, and it is impossible to form a tight hard coat on the workpiece. In the case where the quantity of emitted electrode material is too small as shown in Fig.8B, the workpiece is excessively melted, and an excessively large quantity of the workpiece is removed which exceeds a quantity of the workpiece appropriate for

the adhesion of a hard coat. According to the rectangular pulse wave-form (for example, shown in Fig.5) of the conventional electric power unit for electric discharge surface treatment, the electrode material is emitted and at the same time the electrode material and the workpiece are melted by one shot of electric discharge. Therefore, it is difficult to ensure an appropriate quantity of electrode material to be supplied. Accordingly, there are problems such as a removal of the workpiece, which is caused by the lack of supply of electrode material, and an insufficient melt of the hard coat which is caused by the excessive supply of electrode material.

Disclosure of the Invention

The present invention has been achieved to solve the above problems. It is an object of the present invention to provide an electric power unit for electric discharge surface treatment and a method of electric discharge surface treatment by which a surface treatment cost can be reduced and a tight hard coat can be formed on a workpiece.

The present invention provides an electric power unit for electric discharge surface treatment by which electric discharge is generated between an electrode for electric discharge surface treatment and a workpiece so that a hard coat is formed on a surface of the workpiece by the energy

of electric discharge, the electric power unit for electric discharge surface treatment comprising: a control means for dividing an electric discharge current pulse into a first pulse width T1 (first peak value Ip1), a second pulse width T2 (second peak value Ip2), · · · , and an n-th pulse width Tn (n-th peak value Ipn) (n is an integer 2 and more), the control means for setting the first pulse width T1 and the first peak value Ip1 so that an electric current density between the electrodes can be in a predetermined range to suppress the emission of electrode material, the control means for setting the k-th pulse width Tk and the k-th peak value Ipk ($2 \leq k \leq n$, k is an integer) so that a quantity of supply of hard coat material by the emission of electrode material can be a predetermined value determined according to a predetermined processing condition.

The present invention provides a method of electric discharge surface treatment for forming a hard coat on a surface of a workpiece by which electric discharge is generated between an electrode for electric discharge surface treatment and the workpiece so that the hard coat is formed on the surface of the workpiece by the energy of electric discharge, the method of electric discharge surface treatment comprising the steps of: dividing an electric discharge current pulse into a first pulse width T1 (first peak value Ip1), a second pulse width T2 (second

peak value Ip2), · · · , and an n-th pulse width Tn (n-th peak value Ipn) (n is an integer 2 and more); setting the first pulse width T1 and the first peak value Ip1 so that an electric current density between the electrodes can be in a predetermined range to suppress the emission of electrode material; and setting the k-th pulse width Tk and the k-th peak value Ipk ($2 \leq k \leq n$, k is an integer) so that a quantity of supply of hard coat material by the emission of electrode material can be a predetermined value determined according to a predetermined processing condition.

Since the present invention is composed as described above, the following effects can be provided.

According to the electric power unit for electric discharge surface treatment and the method for electric discharge surface treatment of the present invention, it is possible to effectively make electrode material adhere onto a surface of a workpiece. Therefore, the cost of surface treatment can be reduced.

Further, it is possible to ensure an appropriate quantity of supply of the electrode material. Therefore, it is possible to form a tight hard coat on the workpiece.

Brief Description of the Drawings

Figs.1A to 1C are views showing an arrangement of an electric power unit for electric discharge surface treatment of an embodiment of the present invention and also showing a voltage impressed between electrodes and also showing an electric discharge current;

Figs.2A to 2C are schematic illustrations showing the circumstances of formation of a hard coat on a workpiece by electric discharge surface treatment in which an electric power unit for electric discharge surface treatment of an embodiment of the present invention is used;

Fig.3 is a view showing a comparison of length of consumption of an electrode between a case in which electric discharge treatment is conducted by a conventional power unit for electric discharge surface treatment and a case in which electric discharge treatment is conducted by a power unit for electric discharge surface treatment of the present invention;

Fig.4 is an arrangement view showing an example of a device used for electric discharge surface treatment;

Fig.5 is a view showing a voltage between electrodes and also showing an electric discharge current pulse in a conventional electric power unit for electric discharge surface treatment;

Figs.6A and 6B are schematic illustrations of adhesion of electrode material to a workpiece;

Fig.7 is a view showing a change in the electric current density and also showing a change in the diameter of an electric discharge arc column by the lapse of time from the start of electric discharge; and

Figs.8A and 8B are photographs of a surface of a workpiece of steel in which electric discharge surface treatment is conducted by one shot of electric discharge current pulse.

Best Mode for carrying out the Invention

Figs.1A to 1C are views showing an electric power unit for electric discharge surface treatment of an embodiment of the present invention, wherein Fig.1A is an arrangement view, Fig.1B is a view showing a voltage between electrodes and also showing an electric discharge current, and Fig.1C is a view showing another example of the electric discharge current. In Figs.1A to 1C, reference numeral 1 is an electrode for electric discharge surface treatment, reference numeral 2 is a workpiece, reference numeral 3 is a processing tank, reference numeral 4 is a processing solution, reference numeral 13 is a group of switching elements, reference numeral 14 is a control means for controlling by turning on and off the group of switching elements 13, reference numeral 15 is an electric power unit, reference numeral 16 is a group of resistors, T1 is a

first pulse width, T2 is a second pulse width, Tr is a recess time, IP1 is a first peak value, and Ip2 is a second peak value. The group of switching elements 13, control means 14, electric power unit 15 and group of resistors 16 correspond to an electric power unit for electric discharge surface treatment to determine a wave-form of the electric discharge current pulse in the process of electric discharge surface treatment.

Next, operation will be explained below. The electrode 1 for electric discharge surface treatment and the workpiece 2 are opposed to each other in the processing solution 4, and a predetermined interval is kept between them by a drive unit not shown in the drawing. The peak value of the electric discharge current is a function of the voltage of the electric power unit 15 and the resistance of a resistor in the group of resistors 16 which is connected in series with a switching element, which is turned on, in the group of switching elements 13. When the switching element in the group of switching elements 13, which is connected in series with a resistor in the group of resistors 16 of high resistance, is turned on by the control means 14, a voltage can be impressed between the electrode 1 for electric discharge surface treatment and the workpiece 2. After a predetermined period of time has passed, electric discharge is generated (the first peak

value Ip1). After the generation of electric discharge has been detected and the first pulse width T1 has passed, the switching element, which has been turned on before, is turned off by the control means 14, and the switching element in the group of switching elements 13, which is connected in series with a resistor of low resistance in the group of resistors 16, is turned on, so that the electric discharge current can be increased (the second peak value Ip2). Then, after the second pulse width T2 has passed, all the switching elements in the group of switching elements 13 are turned off by the control means 14. Further, after the recess time Tr has passed, the switching element in the group of switching elements 13 is selectively turned on again by the control means 14. When the above operation is repeated, electric discharge surface treatment is conducted. As described above, the peak value of the electric discharge current can be controlled by selectively turning on and off the switching element in the group of switching elements 13 by the control means 14.

The electric discharge current pulse may be like a step as shown in Fig.1B. Alternatively, the electric discharge current pulse may be like a slope as shown in Fig.1C. The electric discharge current pulse can be increased like a slope by the method in which inductance is inserted in series into the electric power circuit of the

electric power unit for electric discharge surface treatment.

Figs.2A to 2C are schematic illustrations showing the circumstances of formation of a hard coat on a workpiece by electric discharge surface treatment in which an electric power unit for electric discharge surface treatment of an embodiment of the present invention is used. In the drawing, reference numeral 1 is an electrode, reference numeral 2 is a workpiece, reference numeral 10 is an electric discharge arc column, and reference numeral 17 is a hard coat formed on the workpiece 2 by the method of the present invention. Fig.2A shows a state corresponding to the first portion of the first pulse width T1 shown in Fig.1B or 1C. Fig. 2B shows a state corresponding to the last portion of the first pulse width T1 shown in Fig. 1B or 1C. Fig.2C shows a state corresponding to the second pulse width T2 portion shown in Fig.1B or 1C.

In Fig. 1B or 1C, the first pulse width T1 and the first peak value Ip1 are set so that the electric current density can be in a predetermined range to suppress the emission of electrode material (Fig.2A), and the diameter of the electric discharge arc column 10 is sufficiently extended in the range of the first pulse width T1 (Fig.2B). Next, under the condition that the diameter of the electric discharge arc column 10 is extended, the group of switching

elements 13 are controlled by the control means 14 so that a quantity of supply of hard coat material by the emission of electrode material can be a predetermined value according to a predetermined processing condition in the second pulse width T2, and the electric discharge current is increased to the predetermined second peak value Ip2. In this way, the hard coat 17 can be effectively formed on the workpiece 2 as shown in Fig.2C.

Concerning the setting values of the first pulse width T1 and the first peak value Ip1 by which the electric current density between the electrodes can be in a predetermined range to suppress the emission of electrode material, and also concerning the setting values of the second pulse width T2 and the second peak value Ip2 by which a quantity of supply of hard coat material to the workpiece can be a predetermined value, the setting values are previously found by experiments. Therefore, those values can be set according to a predetermined processing speed, a state of the surface of the hard coat and a processing condition such as a quantity of consumption of the electrode.

For example, data such as a quantity of consumption of the electrode for electric discharge surface treatment, a state of the surface of the hard coat formed on the workpiece and a productivity of the surface treatment work

are previously collected by experiments in the case where the parameters of the electrode such as material of the electrode for electric discharge surface treatment, composition of the electrode material and hardness of the electrode material and the parameter of material of the workpiece are changed and also in the case where the parameters such as first pulse width T1, second pulse width T2, first peak value Ip1 and second peak value Ip2 are changed. By using the above data, according to the processing conditions such as a predetermined processing speed, a state of the surface of the hard coat and a consumption of the electrode, the first pulse width T1 and the first peak value Ip1, by which the electric current density between the electrodes in a predetermined range to suppress the emission of electrode material can be determined, may be set, and also the second pulse width T2 and the second peak value Ip2, by which a quantity of supply of hard coat material to the workpiece can be a predetermined value, may be set.

Fig.3 is a view showing a comparison of length of consumption of an electrode between a case in which electric discharge treatment is conducted by a conventional power unit for electric discharge surface treatment and a case in which electric discharge treatment is conducted by a power unit for electric discharge surface treatment of

the present invention, wherein the comparison is made under the condition that the thickness of the hard coat formed on the workpiece is made to be the same. In this case, the electric discharge current pulse created by the conventional electric power unit for electric discharge surface treatment is a rectangular wave, the peak value Ip of which is 8A and the pulse width T of which is 8 μs. Concerning the electric discharge current pulse created by the electric power unit for electric discharge surface treatment, the first pulse width T1 is 8 μs, the first peak value Ip1 is 2A, the second pulse width T2 is 8 μs, and the second peak value Ip2 is 8A. In Fig.3, in the case of the conventional electric discharge current pulse, the length of consumption of the electrode is approximately 500 μm, and in the case of the electric discharge current pulse of the present invention, the length of consumption of the electrode is approximately 200 μm. That is, it can be understood that the consumption of the electrode in the case of the electric power unit for electric discharge surface treatment of the present invention is much smaller than the consumption of the electrode in the case of the conventional electric power unit for electric discharge surface treatment.

According to the electric power unit for electric discharge surface treatment of the present invention, it is

possible to effectively make electrode material adhere onto a surface of a workpiece. Therefore, the cost of surface treatment can be reduced. Further, it is possible to ensure an appropriate quantity of supply of the electrode material. Therefore, it is possible to form a tight hard coat on the workpiece.

In the above explanation, the peak value of the electric discharge current is like two steps, however, it should be noted that the electric discharge current is like three or more steps. In each section of the pulse width, the electric current of the electric discharge current pulse may not be constant or may not be like a slope but the electric current may be a predetermined time function.

Industrial Applicability

As explained above, the electric power unit for electric discharge surface treatment and the method of electric discharge surface treatment of the present invention are suitable for the surface treatment industry in which a hard coat is formed on a workpiece.